U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE
SUBCOMMITTEE ON RESEARCH

HEARING CHARTER

The National Nanotechnology Initiative: Review and Outlook

Wednesday, May 18, 2005
10:00 a.m. - Noon
2318 Rayburn House Office Building

1. Purpose

On Wednesday, May 18, 2005, the Research Subcommittee of the Committee on Science of the House of Representatives will hold a hearing to review the activities of the National Nanotechnology Initiative (NNI).

2. Witnesses

Mr. Scott Donnelly is the Senior Vice President for Global Research for the General Electric Company.

Dr. John Kennedy is Director of the Center for Advanced Engineering Fibers and Films (CAEFF) at Clemson University. CAEFF is a National Science Foundation-supported Engineering Research Center.

Dr. John Cassady is Vice President for Research at Oregon State University (OSU). OSU plays a leading role in the Oregon Nanoscience and Microtechnologies Institute.

Dr. Alain Kaloyeros is the President of Albany NanoTech, which is a university-based collection of research centers and user facilities. Dr. Kaloyeros is also a professor of nanoscience and Vice President and Chief Administrative Officer of the College of Nanoscale Science and Engineering at the University at Albany – State University of New York.

3. Overarching Questions

- Which fields of science and engineering present the greatest opportunities for breakthroughs in nanotechnology, and which industries are most likely to be altered by those breakthroughs in both the near-term and the longer-term?

- What are the primary barriers to commercialization of nanotechnology, and how can these barriers be overcome or removed? What is the federal government's role in facilitating the commercialization of nanotechnology innovations, and how can the current federal nanotechnology program be strengthened in this area?

- What is the workforce outlook for nanotechnology, and how can the federal government and universities help ensure there will be enough people with the relevant skills to meet the nation's needs for nanotechnology research and development and for the manufacture of nanotechnology-enabled products?

4. Brief Overview

- In December 2003, the President signed the *21st Century National Nanotechnology Research and Development Act* (P.L. 108-153), which originated in the Science Committee. This Act provided a statutory framework for the interagency National Nanotechnology Initiative (NNI), authorized appropriations for nanotechnology research and development (R&D) activities through fiscal year 2008 (FY08), and enhanced the coordination and oversight of the program. Funding for the NNI has grown from $464 million in fiscal year 2001 (FY01) to $1.1 billion in FY05, and 11 agencies currently have nanotechnology R&D programs.

- In addition to federal investments, state governments and the private sector have become increasingly involved in supporting nanotechnology. In 2004, the private sector in the U.S. invested roughly $2 billion in nanotechnology research, while states invested roughly $400 million. The state investment is primarily spent on infrastructure and research at public universities, while the private funding focuses on applied research and development activities at small and large companies, and funding for start-up nanotechnology ventures.

- The *21st Century National Nanotechnology Research and Development Act* required that a National Nanotechnology Advisory Panel (NNAP) biennially report to Congress on trends and developments in nanotechnology science and engineering and on recommendations for improving the NNI. The first such report will be released on May 18. Its recommendations include strengthening federal-industry and federal-state cooperation on nanotechnology research, infrastructure, and technology transfer, and broadening federal efforts in nanotechnology education and workforce preparation.

5. Background

Overview of Nanotechnology

The National Academy of Sciences describes nanotechnology as the "ability to manipulate and characterize matter at the level of single atoms and small groups of atoms." An Academy report describes how "small numbers of atoms or molecules ... often have properties (such as strength, electrical resistivity, electrical conductivity, and optical absorption) that are significantly different from the properties of the same matter at either the single-molecule scale or the bulk scale." Scientists and engineers anticipate that nanotechnology will lead to "materials and systems with dramatic new properties relevant to virtually every sector of the economy, such as medicine, telecommunications, and computers, and to areas of national interest such as homeland security."[1]

Nanotechnology is an enabling technology and, as such, its commercialization does not depend specifically on the creation of new products and new markets. Gains can come from incorporating

[1] *Small Wonders, Endless Frontiers: A Review of the National Nanotechnology Initiative*, National Research Council/National Academy of Sciences, 2002.

nanotechnology into existing products, resulting in new and improved versions of these products. Examples could include faster computers, lighter materials for aircraft, less invasive ways to treat cancer, and more efficient ways to store and transport electricity. Some less-revolutionary nanotechnology-enabled products are already on the market, including stain-resistant, wrinkle-free pants, ultraviolet-light blocking sunscreens, and scratch-free coatings for eyeglasses and windows.

In October 2004, a private research firm released its most recent evaluation of the potential impact of nanotechnology. The analysis found that, in 2004, $13 billion worth of products in the global marketplace incorporated nanotechnology. The report projected that, by 2014, this figure will rise to $2.6 trillion—15 percent of manufacturing output in that year. The report also predicts that in 2014, ten million manufacturing jobs worldwide—11 percent of total manufacturing jobs—will involve manufacturing these nanotechnology-enabled products.[2]

National Nanotechnology Initiative

The National Nanotechnology Initiative (NNI) is a multi-agency research and development (R&D) program. The goals of the NNI, which was initiated in 2000, are to maintain a world-class research and development program; to facilitate technology transfer; to develop educational resources, a skilled workforce, and the infrastructure and tools to support the advancement of nanotechnology; and to support responsible development of nanotechnology. Currently, 11 federal agencies have ongoing programs in nanotechnology R&D; funding for those activities is shown in Table 1. Additionally, 11 other agencies, such as the Food and Drug Administration, the U.S. Patent and Trademark Office, and the Department of Transportation, participate in the coordination and planning work associated with the NNI.

Table 1. Funding for the National Nanotechnology Initiative (Dollars in Millions)

	FY04 Actual	**FY05 Estimated**	**FY06 Proposed**
National Science Foundation	256	338	344
Department of Defense	291	257	230
Department of Energy	202	210	207
National Institutes of Health	106	142	144
National Institute of Standards and Technology	77	75	75
National Aeronautics and Space Administration	47	45	32
Environmental Protection Agency	5	5	5
National Institute for Occupational Safety & Health	0	3	3
U.S. Department of Agriculture	2	3	11
Department of Justice	2	2	2
Department of Homeland Security	1	1	1
Total	**989**	**1081**	**1054**

Source: The National Nanotechnology Initiative—Supplement to the Presidents FY06 Budget Request

[2] Lux Research, "Sizing Nanotechnology's Value Chain," October 2004.

In 2003, the Science Committee wrote and held hearings on the *21st Century National Nanotechnology Research and Development Act*, which was signed into law on December 3, 2003. The Act authorizes $3.7 billion over four years (FY05 to FY08) for five agencies (the National Science Foundation, the Department of Energy, the National Institute of Standards and Technology, the National Aeronautics and Space Administration, and the Environmental Protection Agency). The Act also: adds oversight mechanisms—an interagency committee, annual reports to congress, an advisory committee, and external reviews—to provide for planning, management, and coordination of the program; encourages partnerships between academia and industry; encourages expanded nanotechnology research and education and training programs; and emphasizes the importance of research into societal concerns related to nanotechnology to understand the impact of new products on health and the environment.

National Nanotechnology Advisory Panel Report

The *21st Century National Nanotechnology Research and Development Act* required the establishment or designation of a National Nanotechnology Advisory Panel (NNAP) to assess and provide advice on the NNI. In July 2004, the President designated the existing President's Council of Advisors on Science and Technology to serve as the NNAP. The NNAP's responsibilities include providing input to the administration on trends and developments in nanotechnology and on the conduct and management of the NNI.

The NNAP is required to report to Congress on its activities every two years, and its first report will be formally released on May 18, 2005. (Its content is described below.) The report assesses the U.S. position in nanotechnology relative to the rest of the world, evaluates the quality of current NNI programs and program management, and recommends ways the NNI could be improved.

<u>Benchmarking</u>

The NNAP report finds that U.S. leads the rest of the world in nanotechnology as measured by metrics such as level of spending (both public and private), publications in high-impact journals, and patents. The report also finds, however, that other countries are increasing their efforts and investments in nanotechnology and are closing the gap with the U.S. Some countries cannot afford to invest as broadly as the U.S., which has supported nanotechnology efforts relevant to a wide range of industries, but these other countries—particularly in Asia—have instead chosen to concentrate their investments in particular areas to make strides in a specific sector. For example, Korea and Taiwan are investing heavily in nanoelectronics while Singapore and China are focusing on nanobiotechnology and nanomaterials, respectively.

<u>NNI Management</u>

The NNAP report finds that the NNI is a well managed program. The report notes that the balance of funding among different areas of nanotechnology is appropriate and emphasizes the importance of investment in a diverse array of fields rather than a narrow focus on a just a few "Grand Challenges." In particular, the NNAP lauds the NNI for advancing the foundational knowledge about control of matter at the nanoscale; creating an interdisciplinary nanotechnology research community and an infrastructure of over 35 nanotechnology research centers, networks, and user facilities; investing in research related to the environment, health, safety, and other societal concerns; establishing nanotechnology education programs; and supporting public outreach.

Recommendations

The NNAP recommends continued strong investment in basic research and notes the importance of recent federal investment in research centers, equipment, and facilities at universities and national laboratories throughout the country (see Appendix A). Such facilities allow both university researchers and small companies to have access to equipment too expensive or unwieldy to be contained in an individual laboratory.

The NNAP also emphasizes the importance of state and industry contributions to the U.S. nanotechnology efforts and recommends that the NNI expand federal-state and federal-industry interactions through workshops and other methods.

The NNAP also recommends that the federal government actively use existing government programs such as the Small Business Innovation Research (SBIR) and the Small Business Technology Transfer (STTR) programs to enhance technology transfer in nanotechnology. All grant-giving agencies are required by law to have SBIR and STTR programs, and some of them specifically target solicitations toward nanotechnology. However, it is hard to get a clear, up-to-date picture of how much funding is actually provided for nanotechnology-related projects in these programs and on what the demand for SBIR/STTR funding in this area is. The NNAP also recommends that federal agencies be early adopters and purchasers of new nanotechnology-related products in cases where these technologies can help fulfill an agency's mission.

The NNAP also finds that the NNI is making good investments in environmental, health, and safety research, and recommends that the federal government continue efforts to coordinate this work with related efforts in industry and at non-profits and with activities conducted in other countries. The NNAP emphasizes the importance of communication with stakeholders and the public regarding research and findings in this area.

Finally, the NNAP emphasizes the importance of education and workforce preparation and recommends that the NNI coordinate with Departments of Education and Labor to improve access to materials and methods being developed for purposes of nanotechnology education and training.

Challenges Ahead

The NNAP notes that successful adoption of nanotechnology-enabled products will require coordination between federal, state, academic, and industrials efforts (including for efficient commercialization of products), training of a suitable high-technology workforce, and development of techniques for the responsible manufacture and use of these products.

Developing a federal strategy to facilitate technology transfer of nanotechnology innovations is a particularly complex challenge because of the wide range of industry sectors that stand to benefit from nanotechnology and the range of time scales at which each sector will realize these benefits. The NNAP report provides examples of various possible nanotechnology applications and when they are expected to reach the product stage (Table 2). The applications cover sectors from information technology and health care to security and energy, and some applications are on the market now, while others are more than 20 years in the future.

Table 2: Areas of Opportunity for Nanotechnology Applications

Time Scale	Nanotechnology Applications
Near-term (1-5 years)	- Nanocomposites with greatly improved strength-to-weight ratio, toughness, etc. - Nanomembranes and filters (including for water purification and desalination) - Improved catalysts with one or more orders of magnitude less precious metal - Sensitive, selective, reliable solid-state chemical and biological sensors - Point-of-care medical diagnostic devices - Long-lasting, rechargeable batteries
Mid-term (5-10 years)	- Targeted drug therapies - Enhanced medical imaging - High efficiency, cost effective solar cells - Improved fuel cells - Efficient technology for water to hydrogen conversion - Carbon sequestration
Long-term (20+ years)	- Drug delivery through cell walls - Molecular electronics - All-optical information processing - Neural prosthetics for treating paralysis, blindness, etc. - Conversion of energy from the environment (thermal or chemical)

Source: Report of the National Nanotechnology Advisory Panel (2005)

As the NNAP report notes, the states are playing an increasing role in nanotechnology. In 2004, state funding for nanotechnology-related projects was $400 million, or approximately 40 percent of the total federal investment. To date, state funding for nanotechnology has been focused on infrastructure—particularly the construction of new facilities—with some research support being provided in the form of matching funds to public universities that receive federal research dollars. In addition to receiving state support, universities and national laboratories also leverage federal investments through industry contributions of funds or in-kind donations of equipment and expertise. The report on a 2003 NNI workshop on regional, state, and local nanotechnology initiatives lists 18 specific examples of these non-federal initiatives.[3] (Witnesses at the hearing will describe the specific approaches being taken in New York, South Carolina, and Oregon.)

In recent years, the focus has been on the construction of nanotechnology facilities, but as these building projects financed by federal, state, and private funding are completed, the nanotechnology community must consider how best to capitalize on these new resources. Specifically, funding will have to be found for operating expenses, and policies that will attract public and private sector users to these facilities will be needed on topics such as collaboration, intellectual property, and usage fees.

The diversity of industry sectors will be a challenge for developing appropriate education and workforce training programs in nanotechnology. The predicted scale and breadth of research and manufacturing jobs related to nanotechnology will require not only specialized programs but also

[3] *Regional, State, and Local Initiatives in Nanotechnology* is the report on a workshop convened on September 30 – October 1, 2003 by the Nanoscale Science, Engineering and Technology (NSET) Subcommittee, the interagency group that coordinates NNI activities. The report is available online at http://www.nano.gov/041805Initiatives.pdf.

integration of nanotechnology-related information into general science, technology, engineering, and mathematics education.

Finally, successful integration of nanotechnology into products will require an understanding of the standards and regulations needed to govern responsible manufacturing and use of nanotechnology-enabled products. Currently, $82 million of the NNI R&D funding is spent on research related to the societal implications of nanotechnology. Of this amount, $38.5 million is specifically directed at environmental, health, and safety research, while the remainder is for the study of economic, workforce, educational, ethical, and legal implications. In addition to this funding, relevant work is also ongoing in other NNI focus areas. One example is the development of measurement techniques at the nanoscale which are necessary to set standards that can be used for quality control of nanotechnology products and to manage compliance with safety regulations. Another example is the study of the basic mechanisms of interaction between nanoscale materials and biological systems, which can provide critical information for health care applications as well as safe use practices.

6. Witness Questions

The witnesses were asked to address the following questions in their testimony:

Questions for Mr. Scott Donnelly:
- What fields of science and engineering present the greatest opportunities for breakthroughs in nanotechnology, and what industries are most likely to be impacted by those breakthroughs in both the near-term and the longer-term?
- What are the primary barriers to commercialization of nanotechnology, and how can these barriers be overcome or removed?
- To what extent has GE made use of university research and of facilities at universities and national laboratories? How important are these resources to GE's research program and how could they be more helpful?

Questions for Dr. John Kennedy:
- How does the Clemson Center for Advanced Engineering Fibers and Films (CAEFF) interact with the private sector? What are the greatest barriers to increased academic/industrial cooperation in nanotechnology?
- How does the state of South Carolina provide support to CAEFF for nanotechnology and other high-technology activities? How does this complement funding from the federal government and the private sector? What, if any, gaps remain?
- What is the workforce outlook for nanotechnology, and how can the federal government and universities help ensure there will be enough people with the relevant skills to meet the nation's needs for nanotechnology research and development and for the manufacture of nanotechnology-enabled products?
- How can federal and state governments, industry, and academia best cooperate to facilitate advances in nanotechnology?

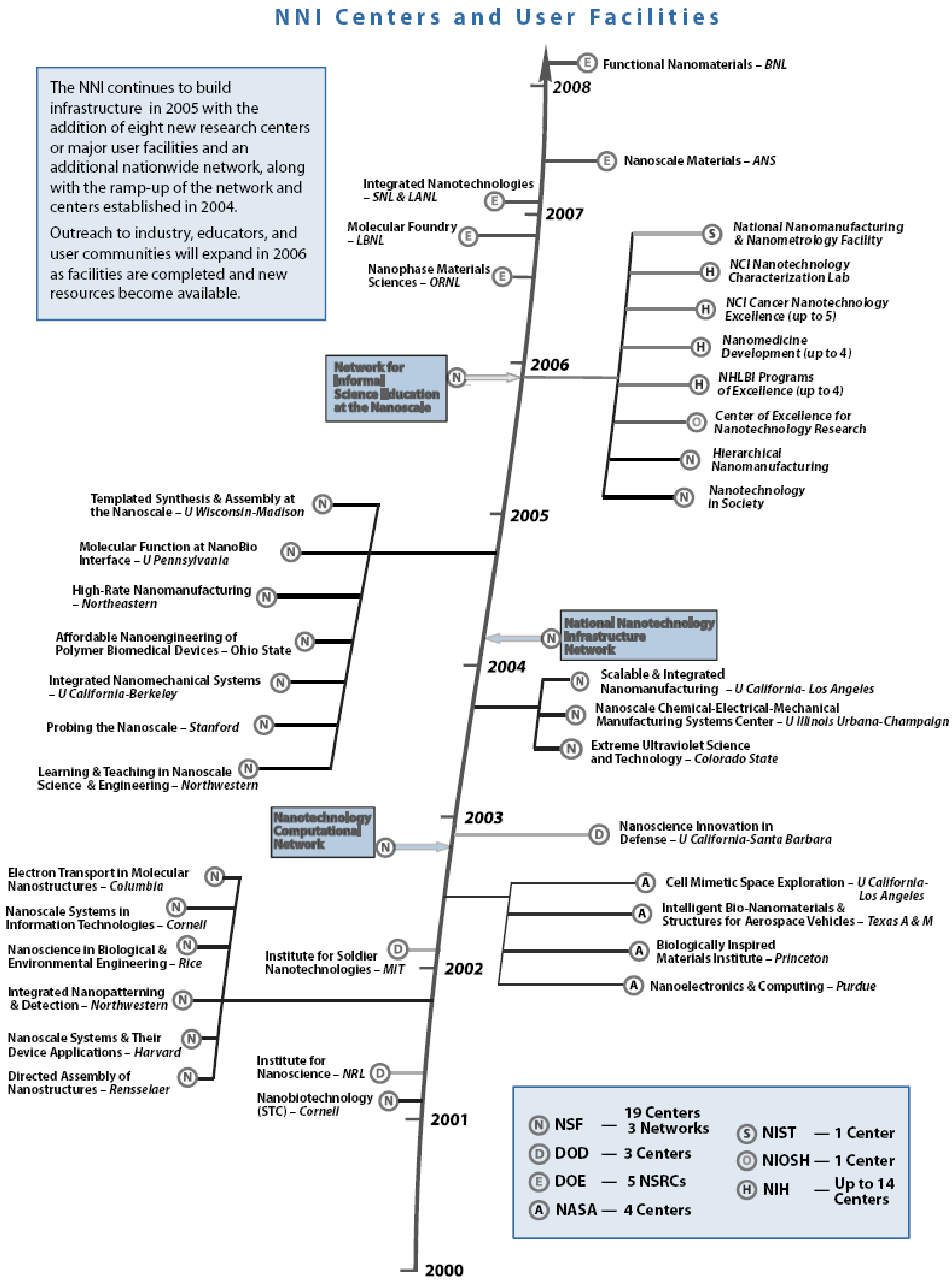
Questions for Dr. John Cassady:

- How do Oregon State University (OSU) and the Oregon Nanoscience and Microtechnologies Institute (ONAMI) interface with the private sector? What are the greatest barriers to increased academic/industrial cooperation in nanotechnology?
- How does the state of Oregon provide support to OSU and ONAMI for nanotechnology and other high-technology activities? How does this complement funding from the federal government and the private sector? What, if any, gaps remain?
- What is the workforce outlook for nanotechnology, and how can the federal government and universities help ensure there will be enough people with the relevant skills to meet the nation's needs for nanotechnology research and development and for the manufacture of nanotechnology-enabled products?
- How can federal and state governments, industry, and academia best cooperate to facilitate advances in nanotechnology?

Questions for Dr. Alain Kaloyeros:

- How does Albany NanoTech interface with the private sector? What are the greatest barriers to increased academic/industrial cooperation in nanotechnology?
- How does the state of New York provide support to Albany NanoTech and the University of Albany College of Nanoscale Science and Engineering? How does this complement funding from the federal government and the private sector? What, if any, gaps remain?
- What is the workforce outlook for nanotechnology, and how can the federal government and universities help ensure there will be enough people with the relevant skills to meet the nation's needs for nanotechnology research and development and for the manufacture of nanotechnology-enabled products?
- How can federal and state governments, industry, and academia best cooperate to facilitate advances in nanotechnology?

Appendix A: National Nanotechnology Initiative Centers and User Facilities



Source: The National Nanotechnology Initiative—Supplement to the Presidents FY06 Budget Request